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Determination of Bed Width of Furrow Irrigation under Wheat at Tibla and Ketar-Genat Irrigation Scheme, Arsi Zone, Ethiopia

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ABSTRACT

An experiment was conducted to investigate the effect of different bed width on yield and water productivity of wheat from (2022-2023) year at Tibila and Ketar-Genet irrigation scheme. Four bed widths (100cm, 80cm, 60cm and 40cm) were arranged in Randomized Complete Block Design with three replications. Recently released bread wheat variety king-bird was used as test crop. From the result, it is found that, Planting wheat on different bed width had a substantial impact on wheat yield and water productivity of the crop. In this study, the highest grain yield (6.23tha^{-1}) were obtained when the bread wheat was grown under T_2 (60cm bed-width) at Tibila irrigation Scheme. Whereas, the highest grain yield (5.93tha^{-1}) were obtained when the bread wheat was grown under T_3 (80cm bed-width) treatments at Ketar-Genat irrigation scheme. In general, the result displayed the production of wheat under 60cm bed width with 14% yield advantage at Tibila and 80cm bed width 16.3% yield advantage at the Ketar-genat irrigation scheme as compared to extremely wider (T_4) and farmer irrigation practice (T_1) respectively. The water productivity among the treatment were also determined in this study where; highest value of 1.05kg m^{-3} was recorded in T_2, at Tibila and T_3 (1.21 kg m^{-3}) at Ketar-Genat irrigation scheme. Here, the result revealed that water productivity was significantly affected by soil characteristics and the width of the bed. The 60cm bed width produced 17.1% in loam soil and 80cm bed width produce 26.4% in clay soil higher water productivity as compared to farmer practice (T_1) at Tibila and Ketar-genet irrigation scheme respectively. T_2 (60cm bed-width) and T_3 (80cm bed-width) were the best treatment to obtain an optimum yield and maximum water use efficiency in Tibila and Ketar-Genat irrigation scheme, respectively. Therefore, it was recommended to the farmer of Tibla irrigation scheme to use 60cm bed width and 80cm bed width for Ketar-Genat irrigation scheme to enhance production and productivity of wheat in the study area.

Keywords: Bed width; Yield; Wheat; King-bird; Water productivity; Irrigation scheme; Loam soil; Clay soil; Tibila; Keter-Genet.

1. Introduction

The aggregate irrigation potentials of Ethiopia have been estimated to be 3.7 million hectares (Aquastat, 2011), however, only about 20 to 23% of this potential is currently put under cultivation (both traditional and modern irrigation systems) (NRMD, 2011). From very little invested irrigation effort, traditional irrigation method has further constrained the cropping intensities, water use efficiency, crop yields and results less contribution of irrigation to the county's economy.

Farmers use surface irrigation systems to irrigate different crops through furrow and border strip techniques due to those systems being low in cost, easier to the farmers to construct, operate and maintain. This method is the most common technique being practiced throughout the world, implying that water distribution is uncontrolled and inefficient (Bilibio, et al., 2011). The efficiency of surface irrigation is lower and in some cases, farmers may lose up to 50% water delivery in deep percolation and runoff (Tadesse, et al., 2016). Among the crop planted by such method, irrigated wheat is newly practiced by the farmers in Ethiopia. This crop is one of the strategic crops in the country, because of its role for food security, import substitution and supply of raw material for agro-processing industry. The gap between demand and supply for wheat crop is widening because of low production due to several factors including traditional irrigation method. (Majeed et al., 2015) reported that as conventional flat planting and flood irrigation of wheat lead to ineffective use of applied nitrogen, poor aeration and leaching, crop lodging, lower water use efficiency, and crusting of the soil surface. Generally, by this method the wheat crop is sown on flat, which often endangers the crop by excess irrigation.

Various techniques of irrigation are used for water saving in agricultural sector throughout the world; a few of these are correlated to preparation of beds for seed to availability of water accordingly. Especially after introducing raised beds method the conservation and efficiency of water was increased as compared to flat basin sowing which was a great breakthrough performance (Connor, et al., 2003). In the bed and furrow irrigation systems, the plants are grown on raised beds which not only use irrigation water more efficiently but also ensure better crop growth under heavy rains (Berkout, et al., 2005). It also provides an opportunity for easy field entry resulting from row orientation on the beds, and irrigation water management is more efficient, less labor required with the use of furrows than conventional flood irrigation (Fische, et al., 2005; Sayre, et al., 2003). Raised bed irrigation method permits more efficient use of irrigation water as compared to the basin or border irrigation (Hassan, et al., 2005). Bed and furrow irrigation in wheat production, save more than 30-35% of irrigation water, 13.4% higher grain yield than flat border irrigation method (M. Ahmad, et al., 2010 and Hussain, et al., 2018).

The spacing between furrows depends on the water movement in the soil, soil texture, crop agronomic requirements as well as on the type of equipment used in the construction of furrows (Eba, 2018). When water is applied to a furrow, it moves vertically under the influence of gravity and laterally by capillarity. Clay soils have more lateral movement of water than sandy soils which favors capillary action (Watson, et al., 1995). In the traditional system of wheat cultivation, farmers totally dependent on their traditional know-how and on the tools and resources available, to make furrow and the spacing between furrows for wheat are unknown. This method of irrigation technique causes farmers to irrigate excess water for wheat production, results in a water shortage problem in the study area. However, furrow and bed irrigation water management practices are not done and evaluated yet in the Tibila and Ketar-Genat irrigation schemes for irrigated cereal crops like wheat.

1.1. Study objectives

The objective of this study was as follows: (1) To evaluate the effect of appropriate bed width of furrow on wheat yield, (2) To improve the wheat yield and water productivity in the selected irrigation schemes, (3) To determine the appropriate bed width of wheat on raised-bed irrigation technique in the scheme, and (4) To determine the appropriate bed width of wheat on clay and loam soil in the scheme.

2. Materials and Methods

2.1. Description of study area

This study was conducted at Tibila and Ketar-Genat Irrigation scheme of Arsi Zone, Oromia National Regional State, Ethiopia. Tibila schemes is bounded within $8^0$89293’N, 0390 03129’E at an altitude of 1303m, whereas Keter-Genet is located at longitude and latitude of 7° 46’ 30" 7° 54’ 0" N and 38° 55’ 30"-39° 4’ 30" E at an altitude of 2430m above sea level. According to the meteorological data obtained from the nearest meteorological station, the annual mean rainfall distribution for Tibila ranges between 500mm to 900mm and 615mm to 1118mm for Ketar-Genet irrigation scheme. The rainfall is mostly characterized by erratic and uneven distribution. The area has a bimodal rainfall pattern, with the small rains occurring from February to April and the main rainfall season, which accounts for the largest total rainfall of the year occurs from July to September at both schemes. The climate of the area is generally warm, the monthly mean temperature for Tibila ranges from (17-23) ^{o}C and (12.7-16.3) for Ketar-Genet.

2.2. Soil Sampling and Analysis

Representative composite soil samples were collected from (0–30) cm soil depths for textural, FC, PWP, ECe, pH and Organic matter (OM) analysis. Bulk density of the field was determined from undisturbed soil samples using core sampler holder having a dimensions of 5.0 cm diameter and 5.0 cm height (98.21 cm^3). The samples were oven-dried for 24 hours at temperature of 105^oc to obtain dry soil sample. Hence, the bulk density (BD) was computed the following Eq.1,

$$BD(\frac{g}{cc}) = \frac{\text{weight of dry soil (g)}}{\text{volume of core sampler}(cm^3)} \qquad \ldots(1)$$

2.3. Treatment and Experimental Design

The treatment was arranged in a randomized complete block design with three replications and it four different bed widths (40cm, 60cm, 80cm and 100cm) with 7m furrow length. The raised beds and furrows were made manually and which have 15cm beds height. 150 kg ha^{-1} seed rate of King-bird bread wheat verity was used for the experiment and 20 cm row spacing was applied by drilling for all treatments. All agronomic practices including weeding, pesticide, and insecticide were done equally for all treatments. A fertilizer rate of 121.1 kg ha^{-1} NPS at planting and 150.13 kg ha^{-1} Urea (50.13 kg ha^{-1} at planting and 100 kg ha^{-1} at the tillering stage) was applied equally for all treatments as per agronomic recommendation. The recommended depth of water was applied by measuring through the Parshall flume.

Table 1. Treatment arrangement

Treatment	Bed width (cm)	No. of Rows
T1	40	2
T2	60	3
T3	80	4
T4	100	5

2.4. Crop Water Requirements and Irrigation Water Management

2.4.1. Crop water requirement

Reference evapotranspiration, ETo was estimated using FAO Penman-Monteith equation from long-term meteorological data collected from Awash Melkasa meteorological station with the help of CROPWAT 8.0 model. Seasonal crop water requirements, ETc was estimated by multiplying the long-term ETo value with the established Kc value (Eq.2),

$$ET_C = ET_O \ x \ K_c \qquad \ldots(2)$$

Where; ETc is Crop evapotranspiration (mm/day), ETo is Reference crop evapotranspiration (mm/day) and Kc is Crop coefficient (fraction).

Due to differences in evapotranspiration during the various growth stages, Kc for a given crop varies over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development,

mid-season and late season. The growth period of wheat in the experimental site is 135 days and it was divided into four stages, viz, initial stage (25 days), development stage (40 days), mid-stage (47 days) and late stage (23 days). Accordingly, the average Kc value for wheat crop under the Tibila irrigation scheme climatic conditions was 1.00 throughout the growing period.

2.4.2. Irrigation water management

Soil moisture level in all plots was brought to field capacity for each treatment in the last irrigation during the common irrigation time. Soil water availability in the experiment was tested from routine measurements of soil moisture content by the gravimetric method. The wet soil samples were weighed and placed in an oven dry at a temperature of 105°c and dried for 24 hours. The gravimetric water content was converted to equivalent depth (D) from Eq.3,

$$\mathrm{D} = \frac{\mathrm{W}_w - W_d}{W_d}\, x\ - = BD\ x\ drz \qquad \ldots(3)$$

Where; D is the depth of available soil moisture (mm), Ww is wet soil weight (gm); Wd is dry soil weight (gm); BD is the soil dry bulk density (gm cm^{-3}) and drz is the sampling depth within the crop root depth (mm).

The soil moisture depleted between irrigation was obtained from Eq.4,

$$\mathrm{IRn} = (\mathrm{FC} - D) \qquad \ldots(4)$$

Where; IRn is the net irrigation requirement (mm) and FC is the soil moisture content at field capacity (mm).

2.4.3. Irrigation scheduling and management

Total available water (TAW) was computed from the moisture content of field capacity and permanent wilting point using equation Eq.5,

$$\mathrm{TAW} = (\mathrm{FC} - PWP)\ x\ BD\ x\ Dz \qquad \ldots(5)$$

Where TAW is the total available water in the root zone (mm), FC and PWP are moisture content at field capacity and permanent wilting point (%) on weight basis respectively and Dz is the root zone depth of wheat at times of each irrigation. For maximum crop production, irrigation schedule was fixed based on p-value. The P-value so-called depletion fraction for winter wheat used in this study was TAW (p = 0.55) according to (Allen, et al.,1998).

Hence, RAW was computed from the Eq.6,

$$\mathrm{RAW} = \mathrm{TAW} \times \mathrm{p} \qquad \ldots(6)$$

Where; RAW is the readily available water or net irrigation depth, IRn (mm), p is the allowable permissible soil moisture depletion fraction and TAW is the total available water in the root depth (mm).

Hence, the IRn of irrigation was computed from Eq.7,

$$\mathrm{IR}_n = \mathrm{TAW} * \mathrm{P} \qquad \ldots(7)$$

Where; IRn is the net irrigation requirement (mm) and p is the depletion fraction.

Irrigation interval, f, was estimated using the following Eq.8,

$$f = \frac{IRn}{ETc} \qquad \ldots(8)$$

Where f is irrigation interval (day) and ETc is mean daily crop water requirement (mm day^{-1}).

Whenever there is rainfall between irrigation, the IRn could be obtained from the Eq.9,

$$\mathrm{IRn} = \mathrm{ETc} - \mathrm{P_{eff}} \qquad \ldots(9)$$

Where P_{eff} is effective rainfall (mm).

The effective rainfall, P_{eff} was estimated using the method given by (Allen *et al.*, 1998) as,

$$\mathrm{P_{eff}} = 0.6 \times \mathrm{P} - \frac{10}{30/31} \quad \text{for month} \leq \frac{70}{30/31}\ \text{mm} \qquad \ldots(10)$$

$$P_{eff} = 0.8 \times P - \frac{24}{30/31} \quad for\ month > \frac{70}{30/31}\ mm \qquad \ldots(11)$$

Where; P is daily rainfall (mm).

2.4.4. Field application efficiency and gross irrigation water requirement

Field irrigation application efficiency (Ea) is the ratio of water directly available in crop root zone to water received at the field inlet. Furrow irrigation could reach a field application efficiency of 70% when it is properly designed, constructed and managed. The average ranges vary from 50 to 70%.

However, a more common value is 60% (FAO, 2002). For this particular experiment, irrigation efficiency was taken as 60%, which is common for surface irrigation method in furrow irrigation. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated based on Eq.12,

$$\mathrm{IR_g} = \frac{\mathrm{IR_n}}{\mathrm{E_a}} \qquad \ldots(12)$$

Where; IR_g is the gross irrigation requirement (mm) and E_a is the field application efficiency (%).

2.4.5. Setting and discharge measurement of Parshall flume

Irrigation water applied to each experimental plot was measured by a 3-inch Parshall flume (PF) made from metal sheet and installed 10 m away from the nearest plot along main canal. The entrance section was set 4 cm above the canal bed to avoid submergence flow.

Only one measurement was required to determine flow rate of free flow condition. This is the height of water from gauge of PF written on two-third surface wall of the entrance section. Calculated gross irrigation was finally applied to each experimental plots based on the treatments proportion. The volume of water applied for every treatment was determined from plot area and depth of gross irrigation requirement.

Time required to irrigate each treatment was calculated from the ratio of volume of applied water to the discharge-head relation of 3-inch PF. Since discharge level might vary at field condition, time required was calculated from 5 to 15 cm head levels. The time required to deliver the desired depth of water into each furrow was calculated using Eq.13,

$$t = \frac{A \times dg}{Q} \quad \ldots(13)$$

Where; dg = gross depth of water applied (mm), t = application time (sec), A = plot Area (m^2) and Q =flow rate (l/s).

2.4.6. Data collection

Plant height (cm): The height wheat was measured from the soil surface to the tip of a spike from 10 randomly tagged plants in the net plot area at physiological maturity.

Number of productive tillers: The tiller number was counted from square box of (1 x 1) m^2 selected randomly per net plot at physiological maturity and converted to m^2.

Number of kernels per spike: It was recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand kernel weight: was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot and weighed with electronic sensitive balance.

Above-ground dry biomass yield: The wheat biomass was determined through weighting plants harvested from the net plot area.

Grain yield: This was also taken by harvesting and threshing the grain yield from the net plot area. The yield were adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

2.4.7. Water Productivity

Water productivity is simply the ratio of the water beneficially used and the quantity of water delivered. This parameter was calculated by dividing wheat harvested from net plot yield in kilogram to unit volume of water in cubic-meter or hectare-meter (Araya *et al*., 2011). The water productivity (WP) also known as the total water use efficiency (Kg m^{-3}) and Irrigation Water Use Efficiency (IWUE, Kg m^{-3}) was calculated based on Eq.14,

$$WP = \frac{Ya}{Twu} \quad \ldots(14)$$

Where; WP = Water productivity (kg/m^3), Ya = Actual yield (kg/ha), Twu = Total water used (m^3/ha).

2.4.8. Data Analysis

The collected data were statistically analyzed using the statistical analysis system (SAS) version 9.0 statistical package using procedure of general linear model (SAS, 2002) for the variance analysis. Mean comparisons was executed using least significant difference (LSD) at 5% probability level when treatments show significant differences to compare differences among treatments mean. Simple correlation analysis was also used to see the association of wheat growth parameters, yield component, yield and water productivity.

3. Results and Discussion

3.1. Selected Soil Physical Properties of Experimental Site

The laboratory results of soil physical properties of Tibila and Ketar-Genat irrigation scheme experimental site were presented in Table 2 below.

Table 2. Average soil physical properties of Tibila irrigation scheme experimental site

Irrigation scheme	**Depth (cm)**	**Bulk density (g/cc)**	**FC (%)**	**PWP (%)**	**TAW**	**Texture**			
			(V/V)	(V/V)	(mm/m)	% Sand	% Silt	% Clay	Class
Tibila	0-100	1.44	27.8	13.7	140.00	41.00	39.00	20.00	Loam
Ketar-Genet	0-100	1.41	29.8	13.7	160.00	31.00	32.00	37.00	Clay

The average result of the soil physical properties from Tibila and experimental site showed that the composition of sand, silt and clay percentage was 41%, 39% and 20%, respectively and that of Keter-Genat was 31%, 32% and 37%, respectively. Thus according to USDA Soil textural classification, the soil of experimental site was classified as Loam and Clay soil for both irrigation schemes respectively. The average bulk density of the experimental soil was found to be 1.44 g/cm^3 at the soil depth of (0 – 15 cm) and Field capacity, Permanent wilting point and Total available water (TAW) of the soil were 27.8%, 13.7%, and 140mm/m, respectively for Tibila scheme (Table 2).

3.2. Chemical properties of soil

Table 3. Average chemical properties of soil at the experimental site

Irrigation scheme	**Depth (cm)**	**pH**	**Total organic matter (% OM)**	**Total Nitrogen (% OC)**	**ECe (ds/m)**
Tibila	0-100	8.43	1.02	2.51	0.25
Ketar-Genet	0-100	5.49	3.58	2.08	0.16

From Table 3, the pH of the experimental site through the analyzed soil was found to be in recommended range of PH soil with average value of 8.43. And also 1.02% organic matter and 2.51% total nitrogen of the soil. An average electrical conductivity of the experimental soil was 0.25 ds/m (Table 3).

3.3. Irrigation water applied to wheat throughout the growth stages

The net volume of irrigation water applied at Tibila and Ketar-Genat irrigation scheme is 644.1mm and 556mm respectively (Table 4). Whereas the total rainfall record in the growing season was 23.8mm for Tibila and 37.mm for Ketar-Genat irrigation scheme respectively. This was deducted from gross irrigation requirement at each irrigation event. The area of furrows per hectare in the wider beds is lower than the narrow beds resulting in received a lower amount of irrigation water in each irrigation event and result in different total IRg (mm).

Table 4. Water applied per growth stage (mm) at both scheme

Irrigation Scheme	**Growth stage**				**IRg (mm)**
	Initial	Development	Mid	Late	
Tibila	174.5	162.0	237.5	70.5	598.10
Ketar-Genet	150.9	139.7	198.4	67.0	556.03

3.4. Effect of d bed-width of furrow irrigation on yield and yield component of wheat

The Effect of different bed-width of furrow irrigation on plant height, number of seed per spikes, spike length, tiller number, above-ground biomass yield and grain yield of bread wheat King-bird varieties at Tibila and Keter-Genet irrigation scheme is indicated in Table 5a and 5b. Accordingly, at Tibila irrigation scheme, wheat grown under bed-width of 60cm (T_2) had the highest plant height, spike length, number of seed per spike and grain yields (Table 5a) and wheat grown under T_3 (80cm bed-width) recorded the highest thousand kernel weight (TKW) and also ranks as the second higher yield among the treatment.

In this scheme, the highest wheat biomass yield of 15.2 t ha^{-1} were recorded on wheat grown under T_2 (60cm bed -width) and shows significant variation at ($P<0.05$) with T_3 and T_4; The second biomass yield 14.3t ha^{-1} which gave 4.2% higher biomass yield over the smallest biomass among the treatment were recorded on T_1(40cm bed-width) and this doesn't shows any significant variation at ($P<0.05$) with other treatment (Table 5a). Here it can be observed that as the bed width increase from 60cm to 100cm the lateral movement of the water in the soil decreased in addition to high evapotranspiration in the area and result in reduction of the biomass production by 10%. Different researchers reported similar result on wheat production. The decreased above-ground biomass in increased bed width is arise from reduced water level due to less lateral movement of water in the soil where evapotranspiration is very high. This might be due to reduction in photosynthesis in which amount of water and chlorophyll is important. According to Guo et al. (2013) reduced water level affects photosynthesis capacity through reduction of chlorophyll content and damage of the reaction center of photo-system.

Similarly, different bed-width of wheat furrow irrigation has shown a significant ($p<0.05$) influence on grain yield per hectare production at Tibila irrigation scheme (Table 5a). The highest grain yield (6.23tha^{-1}) which is 14% higher over the smallest gain yield were obtained when the bread wheat was grown under T_2 (60cm bed-width) and show significant variation at ($P<0.05$) with T_1 (40cm bed-width) and T_4 (100cm bed-width) treatments. The second grain yield 5.9 t ha^{-1} which gave 9% higher grain yield over the smallest yield among the treatment were recorded under T_3 (80cm bed-width).

Table 5a. Effect of bed-width on grain yield and yield components of bread at Tibila irrigation scheme during (2022-2023) year

Treatments	Bed-width (cm)	PH (cm)	NT	S/S	SL (cm)	BMY (ton/h)	GY (t/h)	TKW
T_1	40	90.10^{ab}	8.27a	50.03^{bc}	7.75^{ab}	13.9^{bc}	5.41^{b}	37.52^{abc}
T_2	60	91.27a	8.13^{ab}	55.36^{a}	8.31^{a}	15.2^{a}	6.23^{a}	37.81^{abc}
T_3	80	89.53^{abc}	6.53^{c}	53.27^{ab}	7.94^{ab}	14.3^{ab}	5.92^{a}	38.03^{a}
T_4	100	87.92^{bc}	6.27^{c}	47.87^{c}	7.71^{b}	13.7bc	5.37b	37.97^{abc}
CV		5.42	19.20	6.52	3.41	10.2	1.43	5.42
Mean		89.71	7.30	51.63	7.93	14.3	5.77	37.81
LSD(0.05)		3.15	1.14	5.32	0.58	0.72	0.49	ns

S/S = Number of seed per spikes, NT = number of tillers and TKW = thousand kernel weight, PH (cm) = Plant height, SL = Spike length, BY = Biomass yield and GY = Grain yield.

Similarly, the effect of different bedwidth on wheat yield and yield component were also determined for Ketar-Genet irrigation scheme as indicated on Table 5b. At this scheme, wheat grown under bedwidth of 80cm (T_3) had the highest spike length, number of seed per spike, above-ground biomass yield and grain yields (Table 5b) and wheat grown under T_2 (60cm bed-width) recorded the highest plant height, tiller number and also ranks as the second higher yield among the treatments.

Whereas the highest thousand kernel weight (TKW) were obtained under treatment T_4 (100cm bed-width). The highest thousand kernel weight (TKW) observed in T_4 may indicate the quality of wheat grown under wider bed in which the plant is free from water logging to take up enough Nitrogen from the soil. This result can be supported by (Majeed et al., 2015), research, reported that conventional narrow bed planting and flood irrigation of wheat lead to ineffective use of applied nitrogen and poor aeration, whereas bed irrigation fevers good nitrogen assimilation of plant and resulting in better seed quality.

Moreover, the highest wheat biomass yield of 15.7 t ha^{-1} were recorded on wheat grown under T_2 (60cm bed-width) and show significant variation at ($P<0.05$) with T_1. The second biomass yield 15.3t ha^{-1} recorded on T_3 (80cm bed-width) and this doesn't shows any significant variation at ($P<0.05$) with all treatments (Table 5b). The significance among the treatments for grain yield was also determined in this scheme. In this analysis different bed-width of wheat furrow irrigation has shown a significant ($p<0.05$) influence on grain yield per hectare production (Table 5b).

The highest grain yield (5.93tha^{-1}) which is 16.3% higher over the smallest gain yield were obtained when the bread wheat was grown under T_3 (80cm bed-width) and show significant variation at ($P<0.05$) with T_1 (40cm bed-width) and T_4 (100cm bed-width) treatments. The second grain yield 5.61t ha^{-1} which gave 11.4% higher grain yield over the smallest yield among the treatment were recorded under T_2 (60cm bed-width) and show significant variation at ($P<0.05$) with T_1 (40cm bed-width).

Generally, it can be observed that as the plant height was higher in narrower beds (40 & 60) cm and shorter when bed width increases, this is might be due to low lateral water movement in wider beds at both schemes. The whole result displayed that the production of wheat under optimal raised bed width had 14% yield advantage at Tibila and 16.3% at the Ketar-genet irrigation scheme as compared to extremely wider (T_4) and farmer irrigation practice (T_1) respectively. This result is agreed with the finding of Soomro et al. (2017), they reported that wheat crop produced 24.65 % yield advantage and Razaq, et al. (2019) found that 13.0 % higher grain yield under optimal raised-bed irrigation compared to conventional irrigation system.

Mollah, et al. (2009) also reported that wheat planting using 70 cm wide beds with two and three plant rows had 21 and 20% yield increments respectively over the conventional method. In addition, the wheat yield was about 16.6% higher with nearly 50% less irrigation water with layering precision land leveling and raised bed planting compared to traditional practices (Jat, et al. (2011). The obvious reason for higher yield production under optimal bed width is due to the effective utilization of land by reducing the number of furrows and a good lateral movement of the water.

Table 5b. Effect of bed-width on grain yield and yield components of bread at Ketar-Genet irrigation scheme during (2022-2023) Year

Treatments	Bed-width (cm)	PH (cm)	NT	S/S	SL (cm)	BMY (ton/h)	GY (t/h)	TKW
T_1	40	87.97^{ab}	8.01^{c}	46.98^{c}	7.40^{cd}	13.8b^{c}	4.97^{c}	37.52^{bc}
T_2	60	88.94^{a}	9.10^{a}	47.88^{bc}	7.48^{bcd}	15.7^{a}	5.61^{ab}	37.82^{abc}
T_3	80	87.41^{abc}	8.78^{ab}	54.39^{a}	8.01^{a}	15.3^{abc}	5.93^{a}	38.97^{abc}
T_4	100	85.71^{bc}	8.05^{bc}	52.10^{ab}	7.93^{ab}	14.7^{abc}	5.12^{bc}	39.03^{a}
CV		4.45	20.10	6.44	2.91	11.1	1.33	4.68
Mean		87.51	8.49	50.34	7.71	14.9	5.41	38.34
LSD(0.05)		3.23	0.73	6.51	0.53	1.7	0.62	1.55

S/S = Number of seed per spikes, NT = number of tillers and TKW = thousand kernel weight, PH (cm) = Plant height, SL = Spike length, BY = Biomass yield and GY = Grain yield.

3.5. Effect of different bed-width on Water Use Efficiency of irrigated wheat

In the determination of optimum bed width for irrigated wheat trial at two schemes, the required amount of irrigation water is applied throughout its growth stage to all treatment. As it is shown on (Table 6) WUE was significantly ($P<0.05$) affected due to different bed width of irrigation at both irrigation scheme. The largest value of 1.05kg m^{-3} was recorded at T_2, which is significantly varied with T_1 (0.87 kgm^{-3}) and T_4 (0.96 kg m^{-3}) at Tibila irrigation scheme.

Similarly, we can observe the water productivity difference at Ketar-Genaet irrigation scheme. The highest water use efficiency were recorded on wheat grown under optimum bed width T_3 and this was significantly varied with T_1 and T_4 at ($P<0.05$) level of significance (Table 6). The area of furrows per hectare in the wider beds is lower than the narrow beds resulting in received a lower amount of irrigation water hence increase water productivity in wider bed width. Generally, the result revealed that water productivity was significantly affected by soil characteristics and the width of the raised bed (Table 6). The optimal raised bed width produced 17.1% in loam soil T_2 (1.02 kg m^{-3}) and 26.4% in clay soil T_3 (1.21 kg m^{-3}) higher water productivity as compared to farmer practice (treatment T_1) at Tibila and Ketar-genet irrigation scheme, respectively. This result indicates that clay soils have good lateral movement than loam soil, and which was a similar finding with the report of Razaq et al. (2019) in Pakistan. The saving of irrigation water by bed planting of wheat ranged from 18%-50% as reported by scientists (Choudhary, et al., 2015; Gupta, et al., 2002). The evident reason for higher water productivity under optimal bed width is due to the effective utilization of land by reducing the number of furrows. Different studies conducted on wheat reveal optimum bed width for specific soil affects water use efficiency of irrigated wheat (Pradhan et al., 2013). Shamsi et al. (2010) for instance reported that water use efficiency of wheat varied from 0.66 to 1.34 kg/m3 between different irrigation regimes.

Table 6. Tibila and Ketar-Genat Irrigation scheme site water productivity

Treatments	Bed-width (cm)	GY (t/h)		Water Used (mm)		WUE (kg m^{-3})	
		Tibila	Ketar/G	Tibila	Ketar/G	Tibila	Ketar/G
T_1	40	5.41^{b}	4.97^{c}	598.1	556.00	0.90^{c}	0.89^{c}
T_2	60	6.23^{a}	5.61^{ab}	598.1	556.00	1.04^{a}	1.01^{ab}
T_3	80	5.92^{a}	5.93^{a}	598.1	556.00	1.00^{ab}	1.10^{a}
T_4	100	5.37^{b}	5.12^{bc}	598.1	556.00	0.90^{c}	0.92^{bc}
CV		1.43	1.33			2.8	2.9
Mean		5.77	5.41			0.97	0.98
LSD (0.05)		0.49	0.62			0.07	0.10

4. Conclusions

Planting wheat on different bed width had a substantial impact on wheat grain yield and water productivity. From the experiment conducted at two irrigation scheme; it is observed that as the optimum bed width recommended for wheat growth different from site to site. In this study, the highest grain yield 6.23 tha^{-1} was obtained when the bread wheat was grown under 60 cm bed-width at Tibila irrigation scheme. Whereas, the highest grain yield 5.93 tha^{-1} were obtained when the bread wheat was grown under 80cm bed width treatments at Ketar-Genat irrigation scheme. The water productivity among the treatment was also determined in this study where; highest value of 1.05kg m^{-3} was recorded at Tibila irrigation scheme and 1.21 kg m^{-3} at Ketar-Genat irrigation scheme. Generally, the result revealed that water productivity was significantly affected by soil characteristics and the width of the raised bed. The optimal raised bed width produced 17.1% in loam soil 1.05 kg m^{-3} and 26.4% in clay soil 1.21 kg m^{-3} higher water productivity as compared to farmer practice at Tibila and Ketar-Genet irrigation scheme respectively. This result indicates that as light clay soils have good lateral water movement than loam soil.

Hence from this study; it can be concluded that planting on its optimum bed width of irrigated wheat for different agro-ecology and soil types will maximize production and productivity of the crop.

5. Recommendations

- It was recommended to the farmers of the Tibla irrigation scheme to use a 60cm bed width of furrow to enhance the production and productivity of wheat on loam soil in the area.
- Similarly, an 80cm bed width of furrow irrigation at Ketar-Genet scheme was recommended for use on clay soil.
- It was also recommended that if similar experiment be conducted on another irrigation scheme to identify the optimum bed width plantation for irrigated wheat at different agro-ecology and soil types in the country.

Declarations

Source of Funding

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Competing Interests Statement

The authors declare that there is no conflict of interest related to the work presented in this paper.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

Both authors took part in literature review, analysis and manuscript writing equally.

Data Availability

There is no research data outside the manuscript file.

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